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(54) Fully integrated thermal inkjet printhead having etched back phosphosilicate glass layer

(57) Described herein is a monolithic printhead formed using integrated circuit techniques. Thin film layers (24, 40-50), including ink ejection elements (24), are formed on a top surface of a silicon substrate (20). The various layers are etched to provide conductive leads (25) to the ink ejection elements (24). At least one ink feed hole (26) is formed through the thin film layers (24, 40-50) for each ink ejection chamber (30). A trench (36) is etched in the bottom surface of the substrate (20) so that ink (38) can flow into the trench and into each ink ejection chamber (30) through the ink feed holes (26) formed in the thin film layers. An orifice layer (28) is formed on the top surface of the thin film layers (24, 40-50) to define the nozzles (34) and ink ejection chambers (30). A phosphosilicate glass (PSG) layer (42), providing an insulation layer beneath the resistive layers (24), is etched back from the ink feed holes (26) and is protected by a passivation layer (46) to prevent the ink (38) from interacting with the PSG layer (42). Other layers may also be protected from the ink (38) by being etched back.

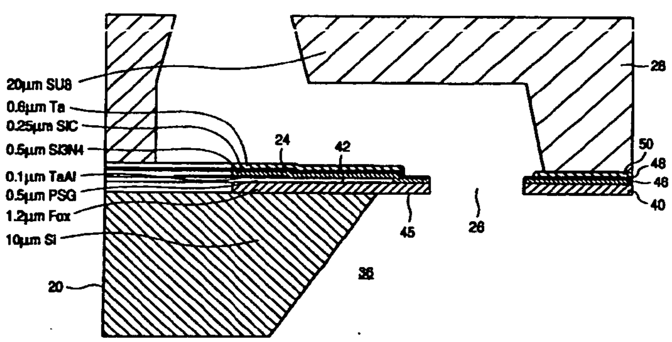

FIG. 4

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FIG. 9 is a top-down view showing in greater detail a portion of a single ink ejection chamber in the printhead embodiment of FIG. 8.

Figs. 10A-10F are cross-sectional views of the printhead of FIG. 8 during various stages of the manufacturing process.

FIG. 11 is a cross-sectional view of a second alternative embodiment of a printhead.

FIG. 12 is a perspective view of a conventional inkjet printer into which the printheads of the present invention may be installed for printing on a medium.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0014] FIG. 1 is a perspective view of one type of inkjet print cartridge 10 which may incorporate the printhead structures of the present invention. The print cartridge 10 of FIG. 1 is the type that contains a substantial quantity of ink within its body 12, but another suitable print cartridge may be the type that receives ink from an external ink supply either mounted on the printhead or connected to the printhead via a tube.

[0015] The ink is supplied to a printhead 14. Printhead 14, to be described in detail later, channels the ink into ink ejection chambers, each chamber containing an ink ejection element. Electrical signals are provided to contacts 16 to individually energize the ink ejection elements to eject a droplet of ink through an associated nozzle 18. The structure and operation of conventional print cartridges are very well known.

[0016] The present invention relates to the printhead portion of a print cartridge, or a printhead that can be permanently installed in a printer, and, thus, is independent of the ink delivery system that provides ink to the printhead. The invention is also independent of the particular printer into which the printhead is incorporated.

[0017] FIG. 2 is a cross-sectional view of a portion of the printhead of FIG. 1 taken along line 2-2 in FIG. 1. Although a printhead may have 300 or more nozzles and associated ink ejection chambers, detail of only a single ink ejection chamber need be described in order to understand the invention. It should also be understood by those skilled in the art that many printheads are formed on a single silicon wafer and then separated from one another using conventional techniques.

[0018] In FIG. 2, a silicon substrate 20 has formed on it various thin film layers 22, to be described in detail later. The thin film layers 22 include a resistive layer for forming resistors 24. Other thin film layers perform various functions, such as providing electrical insulation from the substrate 20, providing a thermally conductive path from the heater resistor elements to the substrate 20, and providing electrical conductors to the resistor elements. One electrical conductor 25 is shown leading to one end of a resistor 24. A similar conductor leads to the other end of the resistor 24. In an actual embodiment, the resistors and conductors in a chamber would be obscured by overlying layers.

[0019] Ink feed holes 26 are formed completely through the thin film layers 22.

[0020] An orifice layer 28 is deposited over the surface of the thin film layers 22 and etched to form ink ejection chambers 30, one chamber per resistor 24. A manifold 32 is also formed in the orifice layer 28 for providing a common ink channel for a row of ink ejection chambers 30. The inside edge of the manifold 32 is shown by a dashed line 33. Nozzles 34 may be formed by laser ablation using a mask and conventional photolithography techniques.

[0021] The silicon substrate 20 is etched to form a trench 36 extending along the length of the row of ink feed holes 26 so that ink 38 from an ink reservoir may enter the ink feed holes 26 for supplying ink to the ink ejection chambers 30.

[0022] In one embodiment, each printhead is approximately one-half inch long and contains two offset rows of nozzles, each row containing 150 nozzles for a total of 300 nozzles per printhead. The printhead can thus print at a single pass resolution of 600 dots per inch (dpi) along the direction of the nozzle rows or print at a greater resolution in multiple passes. Greater resolutions may also be printed along the scan direction of the printhead. Resolutions of 1200 or greater dpi may be obtained using the present invention.

[0023] In operation, an electrical signal is provided to heater resistance 24, which vaporizes a portion of the ink to form a bubble within an ink ejection chamber 30. The bubble propels an ink droplet through an associated nozzle 34 onto a medium. The ink ejection chamber is then refilled by capillary action.

[0024] FIG. 3 is a perspective view of the underside of the printhead of FIG. 2 showing trench 36 and ink feed holes 26. In the particular embodiment of FIG. 3, a single trench 36 provides access to two rows of ink feed holes 26.

[0025] In one embodiment, the size of each ink feed hole 26 is smaller than the size of a nozzle 34 so that particles in the ink will be filtered by the ink feed holes 26 and will not clog a nozzle 34. The clogging of an ink feed hole 26 will have little effect on the refill speed of a chamber 30 since there are multiple ink feed holes 26 supplying ink to each chamber 30. In one embodiment, there are more ink feed holes 26 than ink ejection chambers 30.

[0026] FIG. 4 is a cross-sectional view along line 4-4 of FIG. 2. FIG. 4 shows the individual thin film layers. In the particular embodiment of FIG. 4, the portion of the silicon substrate 20 shown is about 10 microns thick. This portion is referred to as the bridge. The bulk silicon is about 675 microns thick.

[0027] A field oxide layer 40, having a thickness of

close to the operating frequency.

[0046] FIG. 7 is a cross-sectional perspective view along line 7-7 in FIG. 6 illustrating a single ink ejection chamber 60.

[0047] In FIG. 7, a silicon substrate 70 has formed on it a plurality of thin film layers 72 (to be identified in FIG. 8), including a resistive layer and an AlCu layer that are etched to form the heater resistors 62. AlCu conductors 63 are shown leading to the resistors 62.

[0048] Ink feed holes 67 are formed through the thin film layers 72 to extend to the surface of the silicon substrate 70. An orifice layer 74 is then formed over the thin film layers 72 to define ink ejection chambers 60 and nozzles 64. The silicon substrate 70 is etched to form a trench 76 extending the length of the row of ink ejection chambers. The trench 76 may be formed prior to the orifice layer. Ink 78 from an ink reservoir is shown flowing into trench 76, through ink feed hole 67, and into chamber 60.

[0049] FIG. 8 is a cross-sectional view along line 8-8 in FIG. 7 showing one-half of chamber 60. The other half is symmetrical with FIG. 8. Unlike the first embodiment, where a portion of the silicon substrate 20 was located directly beneath the heater resistors to sink heat from the resistors, the structure of FIG. 8 uses a metal layer beneath the heater resistors to draw heat away from the resistors and transfer the heat to the substrate and to the ink itself.

[0050] An insulating layer of field oxide 90, having a thickness of 1.2 microns, is formed over the silicon substrate 70 (FIG. 7) prior to the trench 76 being formed. The portion of the printhead in FIG. 8 is shown after the trench 76 is formed so the substrate 70 is not shown in the field of view.

[0051] A PSG layer 92 having a thickness of 0.5 microns is then deposited over oxide 90. As described with respect to FIG. 4, the oxide and PSG layers provide electrical insulation and thermal conductivity between the heater resistor and the underlying conductive layers, as well as provide increased mechanical support of the bridge extending between the remaining silicon substrate portions after the trench 76 is etched. Also, as previously mentioned, the PSG layer 92 is pulled back from the ink feed hole 67 to prevent contact with the ink which would otherwise react with the PSG.

[0052] Formed over the PSG layer 92 is a resistive layer of tantalum aluminum, having a thickness of 0.1 microns. An AlCu layer (not shown) is formed over the TaAl layer. The TaAl layer and AlCu layer are etched as previously described to form the various heater resistors 62 and conductors 63 (FIG. 7).

[0053] A layer of nitride 96, having a thickness of 0.5 microns, is then formed over the resistors 62 and AlCu conductors, followed by a layer of silicon carbide 98, having a thickness of 0.25 microns. The nitride/carbide layers are etched to expose portions of the AlCu conductors.

[0054] An adhesive layer 100 of tantalum, having a thickness of 0.6 microns, is then deposited, followed by a conductive layer of gold. Both layers are then etched to form gold conductors electrically contacting certain AlCu conductors leading to heater resistors 62 and ultimately terminating in bonding pads along edges of the substrate. In one embodiment, the gold conductors are ground lines.

[0055] The ink feed holes 67 are then etched through the thin film layers (or patterned during fabrication of the thin film layers). The orifice layer 74 is deposited and etched to form chambers 60 and nozzles 64. Nozzles 64 may also be formed by laser ablation.

[0056] The back side of the substrate 70 (FIG. 7) is then masked and etched using a TMAH etch to form the trench 76, extending the length of a row of ink ejection chambers 60. Any one of several etch techniques could be used, wet or dry. Examples of dry etches include XeF2 and SiF6. Examples of appropriate wet etches include Ethylene Diamine Pyrocatechol (EDP), Potassium Hydroxide (KOH), and TMAH. Other etches may also be used. Any one of these or a combination thereof could be used for this application.

[0057] The trench 76 may have a width of approximately one ink ejection chamber or may have a width that encompasses multiple rows of ink ejection chambers. The trench may be formed at any time during the fabrication process.

[0058] After the trench 76 is formed, an adhesion layer 101 of tantalum (Ta), having a thickness of 0.1 microns, is formed on the back side of the wafer overlying the field oxide 90. A heat conducting layer 102 of, for example, gold (Au), having a thickness of 1.5 microns, is then formed over the adhesion layer 101. Another adhesion layer 103 of tantalum, having a thickness of 0.1 microns, is then formed over the heat conducting layer 102.

[0059] FIG. 9 is a top-down view of one-half of an ink ejection chamber 60 in the printhead of FIG. 6. FIG. 9 illustrates the etching of the various layers and is to be taken in conjunction with FIG. 8. Starting with the ink feed hole 67, the oxide and passivation layers 90, 96, and 98 form a shelf approximately 2 microns long. The shelf length could be other sizes, for example, 1-100 microns. The tantalum layer 100 (used as an adhesive layer for gold conductors) is shown extending 1 micron beyond the PSG layer 92, and the PSG layer 92 is shown extending 2 microns beyond the resistor 62.

[0060] Figs. 10A-10F are cross-sectional views of a portion of the wafer during various steps during the manufacturing of the printhead of FIG. 8. Conventional deposition, masking, and etching steps are used unless otherwise noted.

[0061] In FIG. 10A, a silicon substrate 70 with a crystalline orientation of (111) is placed in a vacuum chamber. Field oxide 90 is grown in a conventional manner. PSG layer 92 is then deposited using conventional techniques. FIG. 10A shows mask 110 being formed over the PSG layer 92 using conventional photolitho-

away from the resistors 24.

[0076] One skilled in the art of integrated circuit manufacturing would understand the various techniques used to form the printhead structures described herein. The thin film layers and their thicknesses may be varied, and some layers deleted, while still obtaining the benefits of the present invention.

[0077] FIG. 12 illustrates one embodiment of an inkjet printer 130 that can incorporate the invention. Numerous other designs of inkjet printers may also be used along with this invention. More detail of an inkjet printer is found in U.S. Patent No. 5,852,459, to Norman Pawlowski et al., incorporated herein by reference.

[0078] Inkjet printer 130 includes an input tray 132 containing sheets of paper 134 which are forwarded through a print zone 135, using rollers 137, for being printed upon. The paper 134 is then forwarded to an output tray 136. A moveable carriage 138 holds print cartridges 140-143, which respectively print cyan (C), black (K), magenta (M), and yellow (Y) ink.

[0079] In one embodiment, inks in replaceable ink cartridges 146 are supplied to their associated print cartridges via flexible ink tubes 148. The print cartridges may also be the type that hold a substantial supply of fluid and may be refillable or non-refillable. In another embodiment, the ink supplies are separate from the printhead portions and are removeably mounted on the printheads in the carriage 138.

[0080] The carriage 138 is moved along a scan axis by a conventional belt and pulley system and slides along a slide rod 150. In another embodiment, the carriage is stationery, and an array of stationary print cartridges print on a moving sheet of paper.

[0081] Printing signals from a conventional external computer (e.g., a PC) are processed by printer 130 to generate a bitmap of the dots to be printed. The bitmap is then converted into firing signals for the printheads. The position of the carriage 138 as it traverses back and forth along the scan axis while printing is determined from an optical encoder strip 152, detected by a photoelectric element on carriage 138, to cause the various ink ejection elements on each print cartridge to be selectively fired at the appropriate time during a carriage scan.

[0082] The printhead may use resistive, piezoelectric, or other types of ink ejection elements.

[0083] As the print cartridges in carriage 138 scan across a sheet of paper, the swaths printed by the print cartridges overlap. After one or more scans, the sheet of paper 134 is shifted in a direction towards the output tray 136, and the carriage 138 resumes scanning.

[0084] The present invention is equally applicable to alternative printing systems (not shown) that utilize alternative media and/or printhead moving mechanisms, such as those incorporating grit wheel, roll feed, or drum or vacuum belt technology to support and move the print media relative to the printhead assemblies. With a grit wheel design, a grit wheel and pinch roller move the media back and forth along one axis while a carriage carrying one or more printhead assemblies scans past the media along an orthogonal axis. With a drum printer design, the media is mounted to a rotating drum that is rotated along one axis while a carriage carrying one or more printhead assemblies scans past the media along an orthogonal axis. In either the drum or grit wheel designs, the scanning is typically not done in a back and forth manner as is the case for the system depicted in FIG. 12.

[0085] Multiple printheads may be formed on a single substrate. Further, an array of printheads may extend across the entire width of a page so that no scanning of the printheads is needed; only the paper is shifted perpendicular to the array.

[0086] Additional print cartridges in the carriage may include other colors or fixers.

[0087] While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the appended claims are to encompass within their scope all such changes and modifications as fall within the true spirit and scope of this invention.

Claims

1. A printing device comprising:

   a printhead, said printhead comprising:

      a printhead substrate (20);

      a plurality of thin film layers (24, 40-50) formed on a first surface of said substrate (20), at least one of said layers forming a plurality of ink ejection elements (24), one of said layers (42) comprising a first material, and one of said layers comprising a protective layer (46) over said layer (42) of first material;

      ink feed holes (26) formed through said thin film layers (24, 40-50); and

      at least one opening (36) in said substrate (20) providing an ink path (38) from a second surface of said substrate, through said substrate, and to said ink feed holes (26) formed in said thin film layers,

      said layer (42) of first material being etched back from said ink feed holes (26) so as to be protected from any fluids (38) entering said ink feed holes (26) by said protective layer (46).

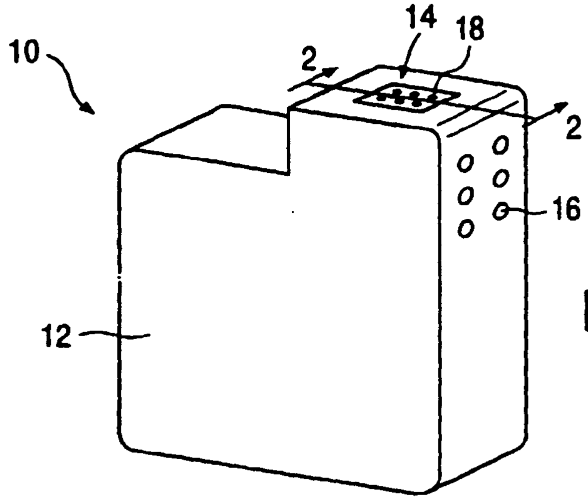

FIG. 1

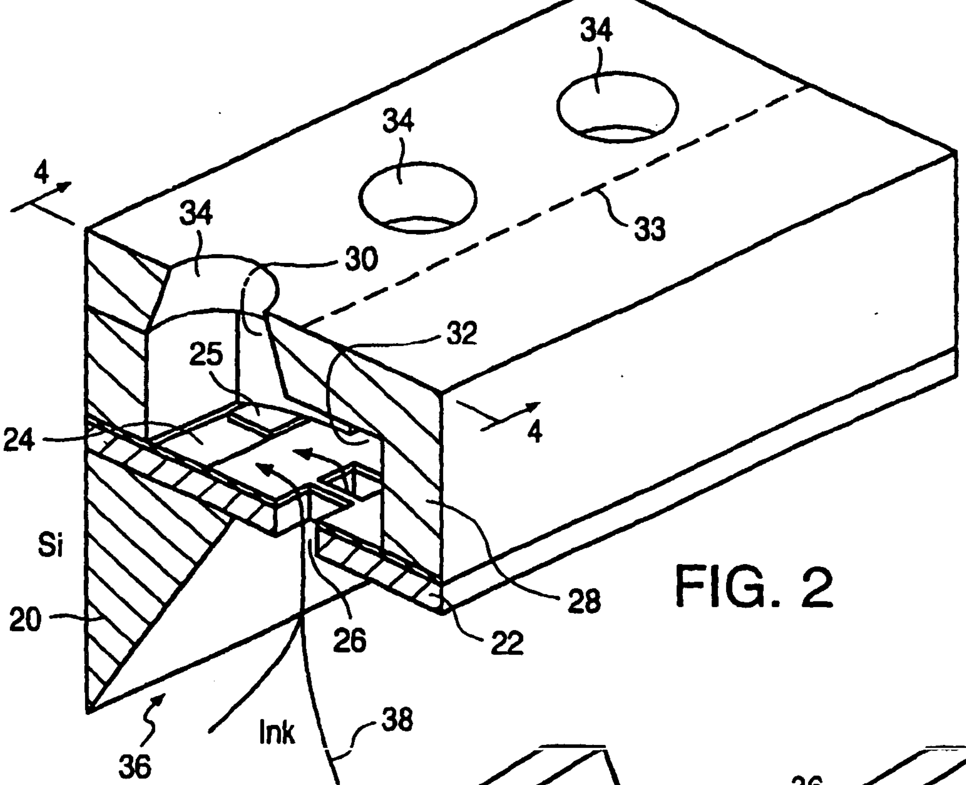

FIG. 2

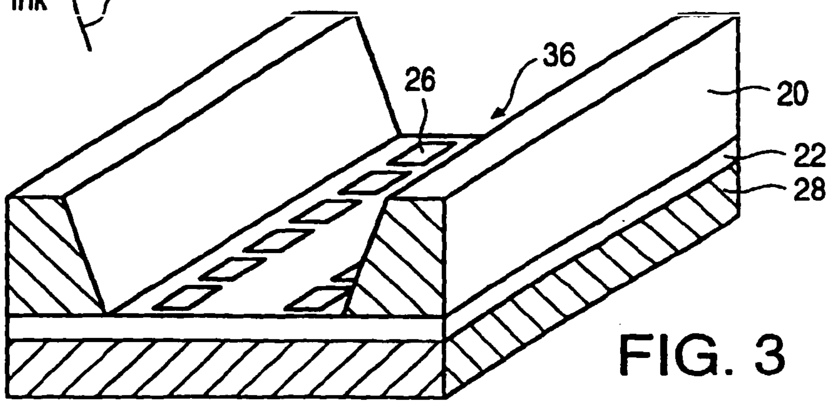

FIG. 3

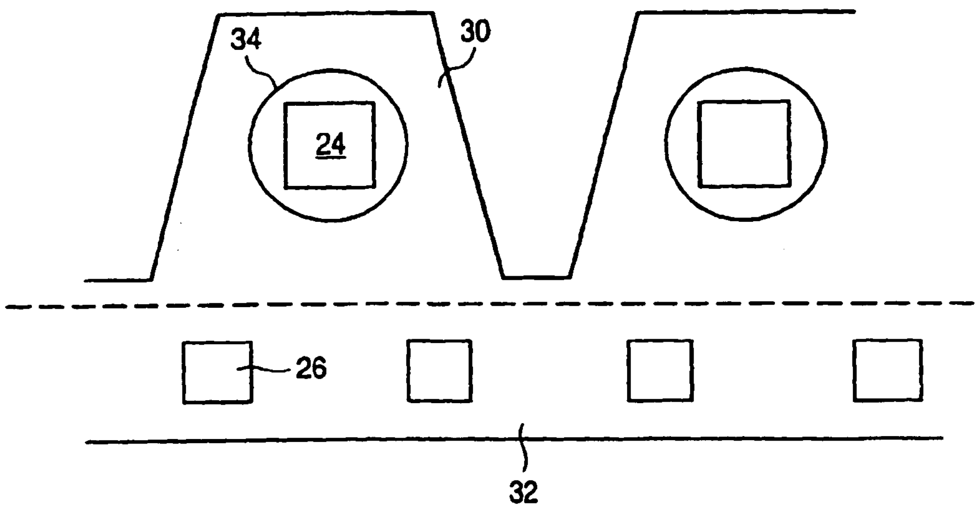

FIG. 5

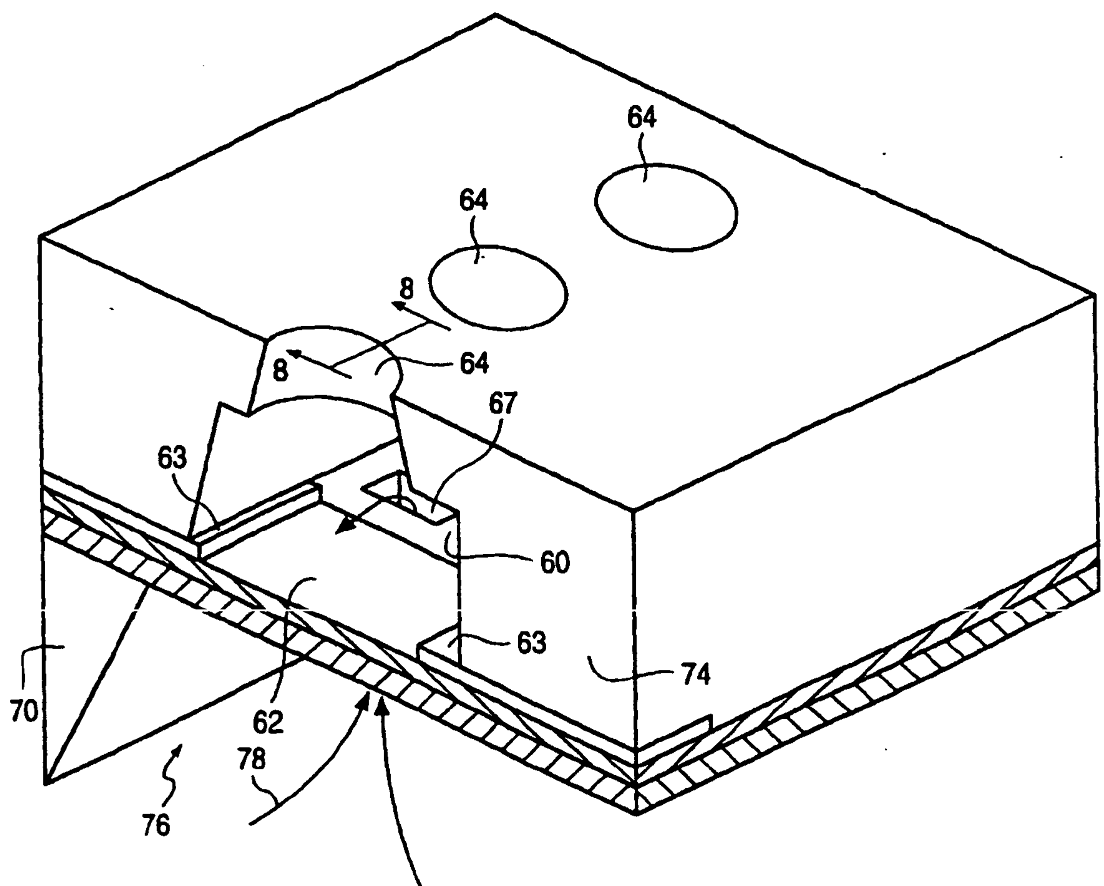

FIG. 7

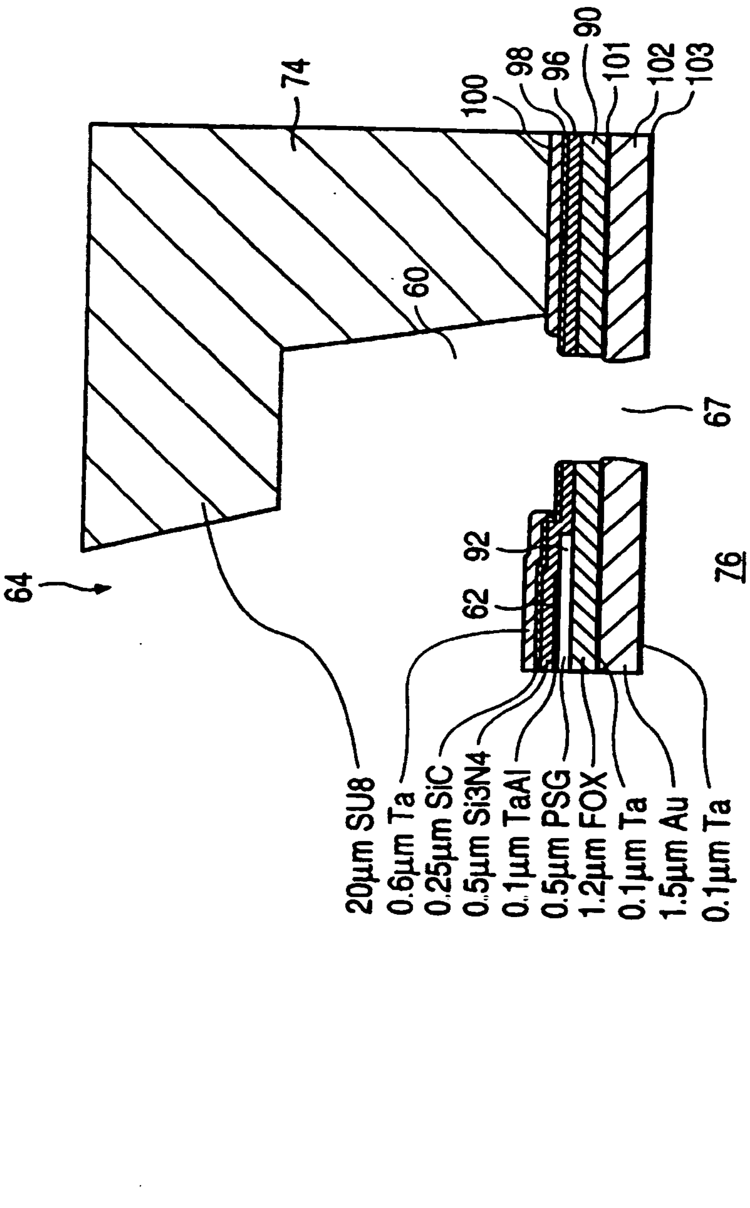
64
74
100
98
96
90
101
102
103
60
67
92
62
76
20µm SU8
0.6µm Ta
0.25µm SiC
0.5µm Si3N4
0.1µm TaAl
0.5µm PSG
1.2µm FOX
0.1µm Ta
1.5µm Au
0.1µm Ta

FIG. 8

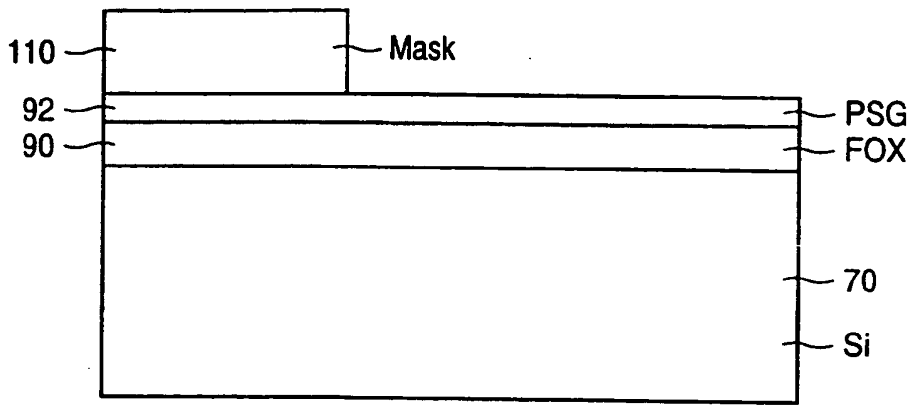

FIG. 10A

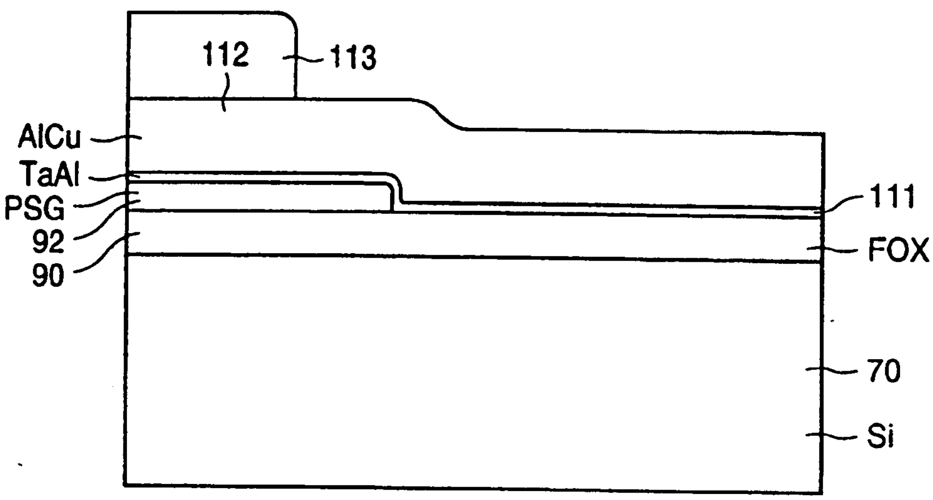

FIG. 10B

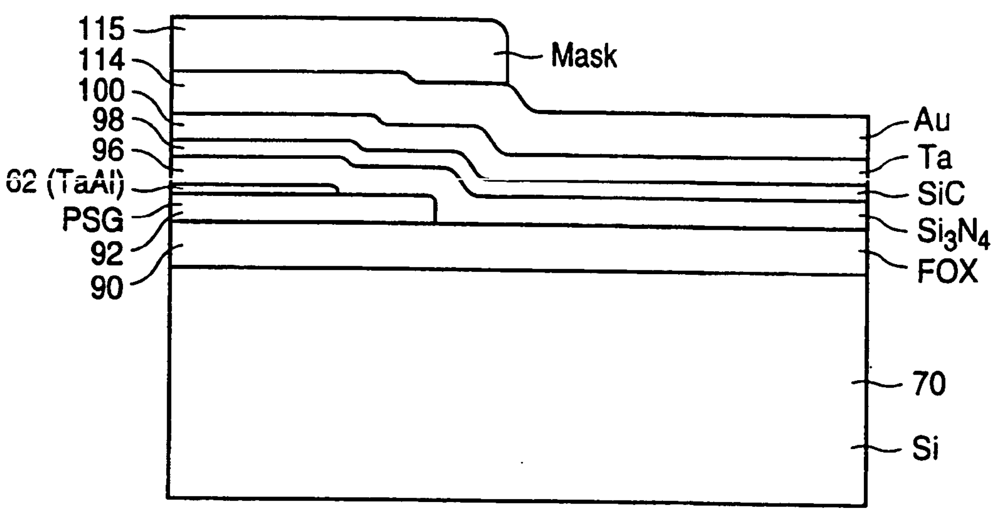

FIG. 10C

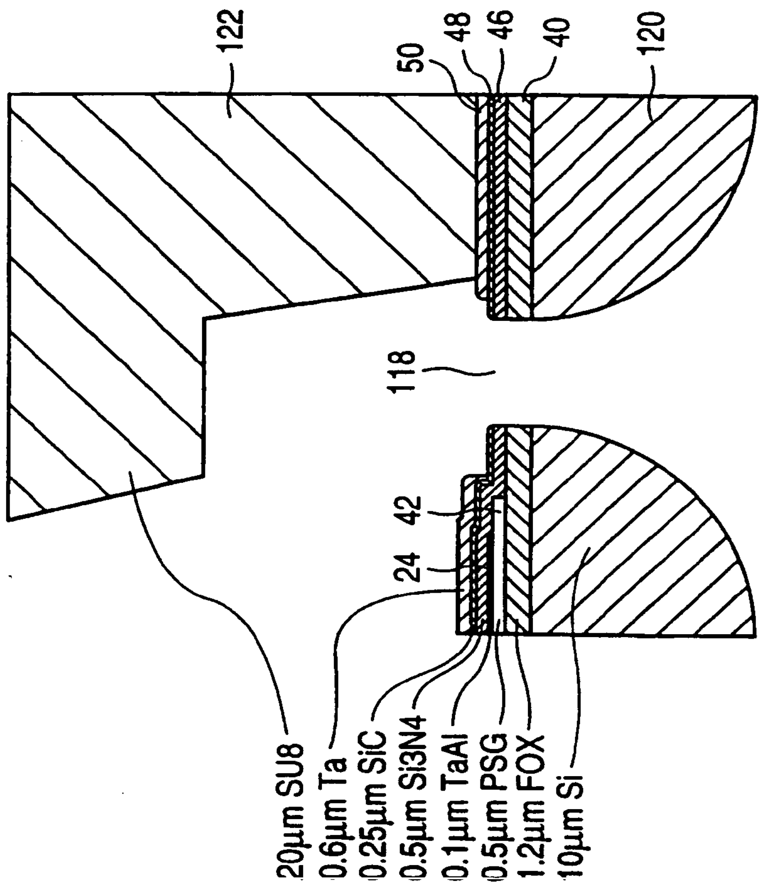
122
50
48
46
40
120
118
42
24
20μm SU8
0.6μm Ta
0.25μm SiC
0.5μm Si3N4
0.1μm TaAl
0.5μm PSG
1.2μm FOX
10μm Si

FIG. 11

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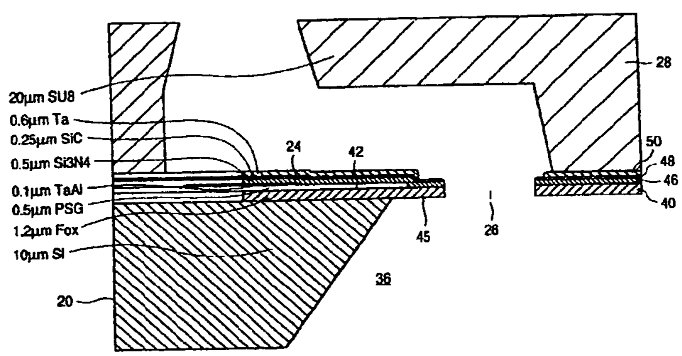

FIG. 4

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